Sampling Episode Report
Holland America Veendam
Sampling Episode 6503

Chapter 2
Wastewater System and Sampling Points

March 2006

2.0 WASTEWATER SYSTEM AND SAMPLING POINTS

This section describes graywater and sewage generation, collection, and treatment on the Veendam, as well as the sample collection points and flow meter locations and installation points used in this sampling episode.

2.1 Wastewater Generation and Collection

The ship's collection, holding, and transfer system (CHT) collects and transfers graywater and sewage generated onboard to the ship's Zenon treatment system. For the purpose of this report, graywater refers to non-sewage wastewaters that are collected by the CHT system. The CHT system is composed of five subsystems, referred to by the ship's crew as the galley, food pulper, accommodations, laundry, and sewage systems. Figure 2-1 is a simplified diagram of the Veendam's graywater and sewage CHT system. Wastewater sources collected by each of the five subsystems are described in Table 2-1. Potable water is used as source water for all ship operations that generate graywater and sewage (e.g., laundry, galley, food pulper, sinks, showers, and toilets). Potable water is produced onboard and bunkered while in port, with each source providing approximately half of the fresh water requirements for the ship.

2.2 Wastewater Treatment

The Veendam is outfitted with a Zenon treatment system, an advanced wastewater treatment system that uses aerobic biological oxidation followed by ultrafiltration and ultraviolet (UV) disinfection. Figure 2-2 is a simplified diagram of the Zenon treatment system.

Wastewater from the laundry, accommodations, food pulper, and galley CHT subsystems culminates in two graywater storage tanks, while the sewage CHT subsystem culminates in four sewage collection tanks. Wastewater pumped from the graywater storage tanks and sewage collection tanks mixes in a common line, flows through two coarse screens operated in parallel, and enters a collection tank. From the collection tank, the wastewater is

pumped to two aerated bioreactor and membrane chamber treatment trains operated in parallel. Operators add defoamer (rarely) and caustic (for pH control) to the bioreactors as needed. From the bioreactors, the wastewater is pumped to the membrane chambers where it flows through the proprietary ZeeWeed® hollow-fiber ultrafiltration membrane system under a vacuum. Particulate matter and mixed liquor (wastewater containing organic matter and biological floc) remain in the membrane chambers. Coarse air diffusers scour the membrane exteriors to remove accumulated solids, and these solids, along with the mixed liquor and particulate matter, overflow from the membrane chambers back to the bioreactor tanks. The system also backwashes the membranes every eight minutes to keep the membranes clean; this backwash remains in the system. Citric acid and sodium hypochlorite are added to the membrane backwash tanks on alternate days to enhance cleaning. In the final stage of treatment, the combined wastewater from the membranes undergoes UV disinfection. The hydraulic residence time of the bioreactor and membrane chamber (i.e., the amount of time the wastewater stays in the treatment system) is less than one day.

According to the ship's crew, the Zenon treatment system can treat 700 m^3 (185,000 gallons) per day of wastewater generated onboard. This is well in excess of its typical daily load, approximately 350 m^3 (9,250 gallons), as determined by interviews with the ship's crew and measured flows collected during this sampling episode.

The Zenon treatment system operates continuously, regardless of the ship's location (e.g., in port, at sea within Alaska waters, at sea outside Alaska waters). The vessel typically continuously discharges treated wastewater from this system overboard. When overboard discharge is restricted, such as when the cruise vessel enters Glacier Bay National Park, the treated effluent is diverted to double-bottom holding tanks, where it is held for eventual discharge overboard outside 12 nautical miles (nm).

The Zenon wastewater treatment system generates two types of residual waste: screening solids (from the 2 coarse screens) and waste biosludge (excess biological mass from the bioreactor). A solids collection tank located directly beneath the screens collects the screening solids and uses a macerator pump to chop the solids. Macerating the solids releases

additional water. Therefore, four to five times per day, the Zenon operator pumps the contents of the solids tank back to the screens to remove excess water. Once a month, the Zenon operator removes approximately 15 to 20 m^3 of screening solids from the solids collection tank and disposes of it onshore.

Waste biosludge is removed (or "wasted") from the bioreactors daily. The Zenon operator calculates the recommended waste biosludge volume to remove by measuring the bioreactor total suspended solids (mixed-liquor suspended solids (MLSS)) concentration. In Alaska, the target MLSS concentration for the Zenon bioreactor is 9,000 to 10,000 mg/L. To maintain the target MLSS concentration, the typical daily biosludge volume wasted is 15 m^3. If additional waste volume is required, e.g., 20 m^3, then the Zenon operator would waste 15 m^3 in the morning and an additional 5 m^3 in the evening. Waste biosludge is held in a double-bottom holding tank for overboard discharge outside of 12 nm from shore.

The ultrafiltration membranes require more intensive cleaning every few weeks for optimal operation. The Zenon operator initiates the membrane cleaning cycle when the differential pressure across the membranes, or transmembrane pressure (TMP), reaches approximately -0.45 bars. The 2-day cleaning cycle requires shutdown of the bioreactor/membrane chamber treatment train. (When one bioreactor/membrane chamber is being cleaned, all wastewater is diverted to the second, parallel bioreactor/membrane chamber.) The first step in the cleaning cycle is the addition of two drums (406 L in total) of sodium hypochlorite to the membrane chamber, plus a sufficient amount of treated wastewater to fill the chamber. The hypochlorite solution remains in the chamber overnight and is then sent to a double-bottom holding tank (the same tank used to hold waste biosludge) for discharge overboard outside 12 nm. The second step is to add 150 kg of citric acid to the membrane chamber, plus a sufficient amount of treated wastewater permeate to fill the chamber. The solution remains in the chamber for six hours and is then sent to the same double-bottom holding tank.

During periods of reduced treatment capacity (e.g., maintenance, cleaning, high TMP), additional untreated graywater storage capacity may be needed. The two graywater

storage tanks routinely used by the treatment system provide a combined holding capacity of 240 m^3. Additional double-bottom holding tanks provide up to 740 m^3 of additional storage capacity, yielding a total holding capacity of 980 m^3. Note that tank piping configurations allow the contents of only some of the additional double-bottom holding tanks to be pumped to the wastewater treatment system. Any untreated graywater stored in tanks that cannot be pumped to the treatment system is held for discharge without treatment outside 12 nm from shore. According to the ship's crew, such discharges are not typical and occur infrequently.

2.3 Wastewater and Residual Sample Collection Points

Samples were taken from the graywater sources (galley, laundry, accommodations, and food pulper); influent to the treatment system (combined graywater and sewage); influent to the UV disinfection portion of the treatment system; effluent from the treatment system; source water (water from the ship's potable water system); wastewater treatment residuals; and incinerator ash. Table 2-1 describes the wastewaters sampled, their sampling point locations, their flow measurement locations (if applicable), and the number of days they were sampled. Table 2-2 provides the same information for the treatment residuals and incinerator ash sampled. In general, graywater source and wastewater treatment residual samples were taken for one 24-hour period, while samples of the influent to and effluent from the treatment system were taken for five 24-hour periods. See Section 3.2 and Table 3-2 for information on the analytes tested.

Samples were collected from the ship's potable water system (source water) to determine if any of the target analytes were present as background contamination. One trip blank was prepared and analyzed for volatile organics to evaluate possible contamination during shipment and handling of samples. Finally, an equipment blank was prepared and analyzed to evaluate possible contamination caused by the sampling equipment.

Samples were not taken directly from the sewage CHT system. In addition, samples could not be collected of wastewater held in double-bottom holding tanks for discharge outside 12 nm from shore (i.e., treated effluent diverted to storage while the ship cruised Glacier

Bay) because (1) double-bottom holding tanks cannot be accessed directly due to safety considerations, and (2) sampling from the holding tank discharge manifold would characterize combined holding tank discharges and not discharges specific to the holding tanks of interest.

2.4 Flow Meter Locations

Strap-on ultrasonic flow meters (Controlotron Model 1010) were installed at three sampling locations to collect flow data and, in some cases, to control automatic composite sample machines (by triggering sample collection after a defined amount of flow passed through the pipe). The first location was near the influent to the wastewater treatment system (SP-6/7; see Table 2-1 for a description of wastewaters and Figure 2-2 for a simplified wastewater treatment system diagram showing sampling points.) This flow meter was installed on the outlet pipe from the screens because there was not a suitable location on the inlet pipe to the screens. The second location was at the effluent from the wastewater treatment system (on the overboard discharge line for the treated effluent, SP-9/10; see Table 2-1 and Figure 2-2). This flow meter was installed on the same piping as the sample tap. The third location was laundry wastewater (SP-1/2; see Table 2-1 and Figure 2-1). This flow meter was installed on the outlet pipe from the laundry wastewater holding tank. The sample tap, however, was installed on the inlet pipe to the laundry wastewater holding tank because there was not a suitable location on the outlet pipe. The flow meter at this location was not used to control sample collection at this sampling point because the flow patterns at the flow meter and sample tap locations were not the same. Therefore, composite sample collection at this sampling point was time-weighted (see Table 3-1 for a description of the sample collection methods).

Sampling points for accommodations and galley wastewaters were located on piping that would not support the installation of strap-on ultrasonic flow meters (see Table 2-1), precluding collection of flow data and flow-weighted composite samples at these sampling points. Time-weighted composite samples were collected at the accommodations and galley wastewater sampling points (see Table 3-1 for a description of the sample collection methods). Flow estimates for the food pulper wastewater were provided by the ship's crew.

In addition, flow data were collected from three of the Veendam's in-line Endress + Hauser Pro-mag series flow meters (see Figure 2-2 for locations). One of these in-line flow meters was on the discharge line from the sewage collection tanks. The second was on the discharge line from the graywater storage tanks. Flow from these two meters combined represents the total flow into the treatment system. The third in-line flow meter from which data were collected was on the effluent from the wastewater treatment system (i.e., on the overboard discharge line for the treated effluent), which was the same location where a strap-on flow meter was installed.

Table 2-1

Wastewater, Sampling Point, and Flow Meter Descriptions
Holland America Veendam

Descriptions of wastewaters sampled, sampling point locations, flow meter locations, and number of days sampled for the Veendam sampling episode (June 20 through June 25, 2004).

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Laundry	Wastewater from laundry equipment and laundry floor drains. It does not include wastewater from dry cleaning operations or passenger laundrettes. All laundry wastewater drains to a single laundry wastewater holding tank.	SP-1/2	Sample tap was installed on the inlet pipe to the laundry wastewater holding tank. Sample tap could not be installed on the holding tank outlet pipe due to commingling with other graywater sources caused by backflow from the graywater main common line.	Strap-on flow meter was installed on the outlet pipe from the laundry wastewater holding tank. Backflow from the graywater main common line did not significantly affect the measured laundry wastewater flows. Strap-on flow meter was not suitable for gravity flow piping (i.e., piping that is not full) at the inlet to the holding tank.	1 (Day 4)
Accommodations	Wastewater from sinks, tubs, and showers in guest and crew rooms, bar sinks, salon sinks and floor drains, most interior deck drains, passenger laundrettes, dry cleaning noncontact cooling water, and non-engine-room shop sinks. Accommodations wastewater is pretreated by gross particle filters as it drains to three accommodations wastewater holding tanks approximately equal in size.	SP-3	Sample tap was installed on the outlet pipe from one of the holding tanks. According to the ship's crew, all three holding tanks receive similar wastewater; therefore, the specific holding tank sampled was selected based on accessibility.	Flow data for accommodations wastewater were not obtained. Strap-on flow meter set-up and calibration procedures were unsuccessful at the outlet pipe from the accommodations wastewater holding tank, most likely due to poor pipe flow conditions such as pipe scaling or extreme aeration. Strap-on flow meter was not suitable for gravity flow piping (i.e., piping that is not full) at the inlet to the holding tank.	1 (Day 4)

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1 and 2-2 for simplified diagrams of the Veendam graywater and sewage CHT and wastewater treatment systems indicating the sampling point and flow meter locations.
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.
(d) Source water samples for pathogen indicator analyses were collected for five days. Source water samples for analysis of all other analytes were collected for one day.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Food Pulper	Wastewater from the Somat food pulper system. Food waste is mixed with water and processed into a slurry. The food slurry is then separated into semi-dry food solids and wastewater (food pulper wastewater). Food solids are incinerated onboard, while food pulper wastewater is routed to a food pulper wastewater holding tank for recirculation back to the Somat system. Three to four times per day, the food pulper wastewater is drained from the holding tank to the wastewater treatment system and replaced with fresh water.	SP-4	Samples were collected from an existing sample tap located on the holding tank, just prior to the times the tank contents were drained to wastewater treatment.	Flow measurements not required. Approximately 22 m^3 of food pulper wastewater is generated per day, according to the ship's crew.	1 (Day 3)
Galley	Wastewater from dishwashers, food preparation, galley sinks, and galley and garbage room floor drains. Galley wastewater drains from each of the two passenger galleys and one crew galley, through three grease traps (one for each galley), into a single combined galley wastewater holding tank. An enzyme is added prior to the grease traps to help degrade grease.	SP-5	Sample tap was installed on the inlet pipe to one of the passenger galley grease traps. According to the ship's crew, all three grease traps receive similar wastewater; therefore, the specific grease trap sampled was selected based on accessibility.	Flow data for galley wastewater were not obtained. Strap-on flow meter was not suitable for gravity flow piping (i.e., piping that is not full) at the inlet to the grease trap. Pipe configurations precluded all other locations.	1 (Day 2)

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1 and 2-2 for simplified diagrams of the Veendam graywater and sewage CHT and wastewater treatment systems indicating the sampling point and flow meter locations.
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.
(d) Source water samples for pathogen indicator analyses were collected for five days. Source water samples for analysis of all other analytes were collected for one day.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Influent to Zenon Treatment System	Combined wastewaters from the five collection, holding, and transfer (CHT) subsystems (laundry, accommodations, food pulper, galley, and sewage). A vacuum CHT system conveys sewage from passenger and crew toilets and urinals. The sewage CHT system also conveys wastewater from medical facility sink and floor drains. Note that samples were not taken directly from the sewage CHT system. Wastewater from the laundry, accommodations, food pulper, and galley CHT subsystems culminates in two graywater storage tanks. The sewage CHT subsystem culminates in four sewage collection tanks (one of the sewage collection tanks also receives 14 m^3/day of treated effluent for dilution). Wastewater from the graywater storage tanks and sewage collection tanks mixes in a common line as it flows to the treatment system.	SP-6/7	Sample tap was installed on the combined graywater and sewage inlet pipe to the treatment system (before the screens).	Strap-on flow meter was installed on the outlet pipe from the screens because there was not a suitable location on the inlet pipe to the screens. The Veendam has in-line flow meters installed on the discharge line from the graywater storage tanks and on the discharge line from sewage collection tanks, prior to the point where the wastewaters are combined for treatment. The combined flow from these two flow meters represents the influent to wastewater treatment.	5
Influent to UV Disinfection part of Zenon Treatment System	Wastewater following treatment by biological oxidation and ultrafiltration but prior to ultraviolet (UV) disinfection.	SP-8	Sample tap was installed on the inlet pipe to the UV disinfection unit.	Flow measurements not required.	5
Effluent from Zenon Treatment System	Final treated wastewater effluent from the Zenon wastewater treatment system. Effluent is typically continuously discharged overboard. Where discharge is prohibited (e.g., Glacier Bay), wastewater is diverted to storage in double-bottom holding tanks for overboard discharge outside 12 nm from shore.	SP-9/10	Sample tap was installed on the effluent pipe from UV disinfection, upstream of the diversion valve that directs wastewater to either overboard discharge or to storage in double-bottom holding tanks. Piping distance from the effluent sample tap to the overboard discharge port is 10.5 m.	Strap-on flow meter was installed on the effluent pipe from UV disinfection just prior to the overboard discharge port and downstream of the diversion valve that directs wastewater to either overboard discharge or storage in double-bottom holding tanks. The Veendam has an in-line flow meter installed at the same location.	5

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1 and 2-2 for simplified diagrams of the Veendam graywater and sewage CHT and wastewater treatment systems indicating the sampling point and flow meter locations.
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.
(d) Source water samples for pathogen indicator analyses were collected for five days. Source water samples for analysis of all other analytes were collected for one day.

Table 2-1 (Continued)

Wastewater Name	Wastewater Description (a)	Sampling Point # (b)(c)	Sampling Point Description (b)	Flow Meter Description (b)	# of Days Sampled
Source Water	Potable water used as source water for all systems that generate wastewater that is treated by the Zenon treatment system.	SP-15	Samples collected from a passenger cabin sink located forward in the ship (i.e., a point farthest in the distribution line).	Flow measurements not required.	5 / 1 (d)

(a) List of wastewater sources may not be comprehensive.
(b) See Figures 2-1 and 2-2 for simplified diagrams of the Veendam graywater and sewage CHT and wastewater treatment systems indicating the sampling point and flow meter locations.
(c) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.
(d) Source water samples for pathogen indicator analyses were collected for five days. Source water samples for analysis of all other analytes were collected for one day.

Table 2-2

Treatment Residuals and Incinerator Ash Descriptions
Holland America Veendam

Descriptions of treatment residuals and incinerator ash sampled, sampling point locations, flow meter locations, and number of days sampled for the Veendam sampling episode (June 20 through June 25, 2004).

Treatment Residual Name	Treatment Residual Description	Sampling Point # (a)(b)	Sampling Point Description (a)	Flow Meter Description	# of Days Sampled
Screening Solids	Solids generated by the screens of the Zenon wastewater treatment system. Screening solids are collected monthly from the solids collection tank for disposal onshore.	SP-11	Sample tap was installed on the solids recirculation loop at the macerating pump.	Flow measurements not required. Approximately 15 to 20 m^3 of screening solids are generated per month, according to the ship's crew.	1 (Day 1)
Waste Biosludge	Waste biosludge removed daily from the bioreactors of the Zenon wastewater treatment system. Waste biosludge is pumped to a double-bottom holding tank for overboard discharge outside of 12 nm from shore.	SP-12	Sample tap was installed on the piping that routes the waste biosludge from the treatment system to the double-bottom holding tank.	Flow measurements not required. Approximately 15 m^3 of waste biosludge is generated per day, according to the ship's crew.	1 (Day 2)
Incinerator Ash	Ash generated from the incineration of trash (e.g., cardboard, paper, plastic) and food solids from the Somat food pulper system. Incinerator ash is collected in incinerator ash storage hoppers for disposal onshore.	SP-13/14	Samples were collected directly from an incinerator ash storage hopper.	Flow measurements not required.	1 (Day 1)

(a) See Figures 2-1 and 2-2 for simplified diagrams of the Veendam graywater and sewage CHT and wastewater treatment systems indicating the sampling point and flow meter locations.
(b) Two sampling point numbers indicate duplicate samples taken at this point for certain analytes. See Section 5.2.3 and Tables 5-3 and 5-4 for details on duplicate sampling.

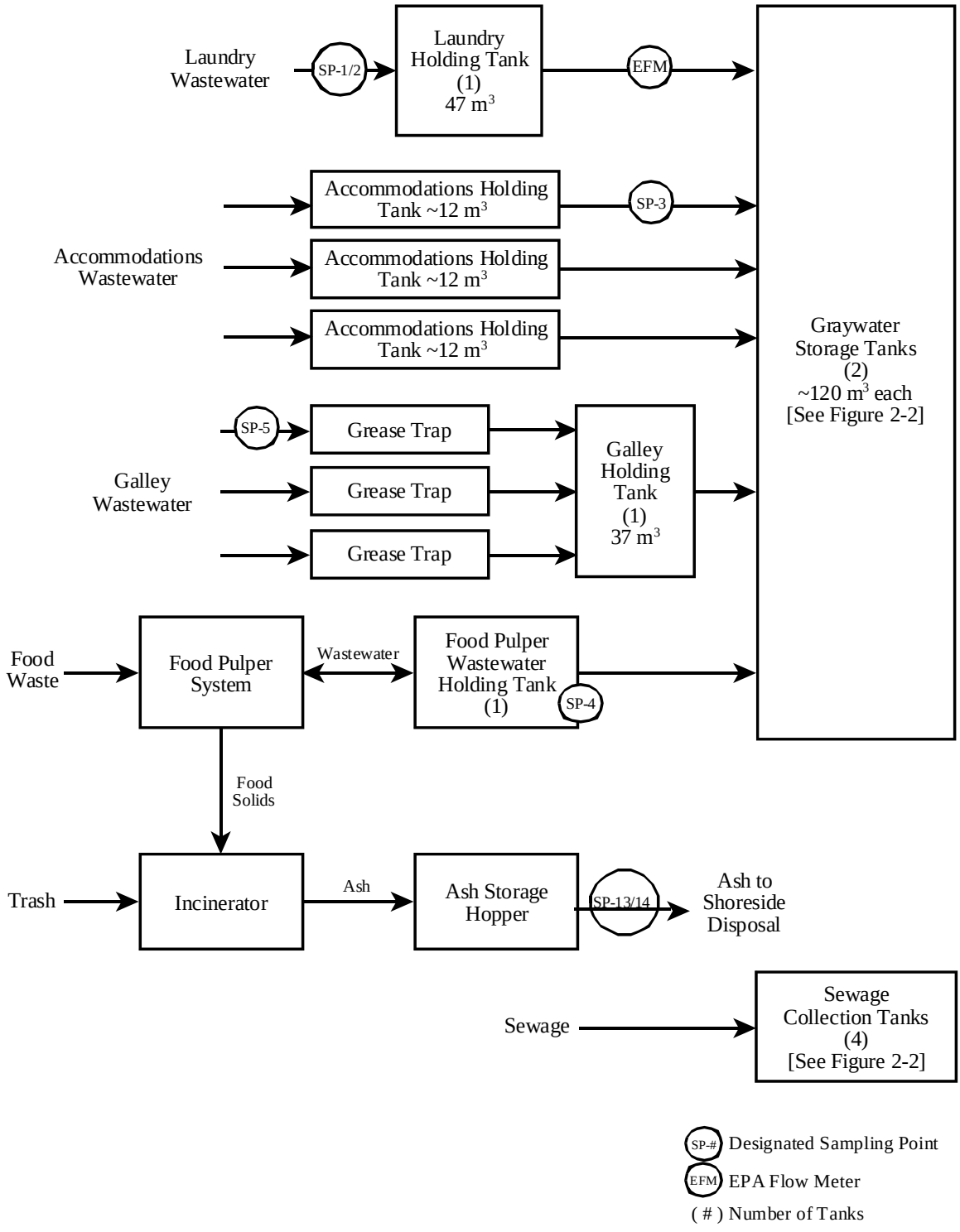

Figure 2-1. Graywater and Sewage Collection, Holding and Transfer System, Holland America Veendam

Simplified diagram of the Holland America Veendam graywater and sewage CHT System. See Table 2-1 for a list of wastewater streams in each wastewater source.

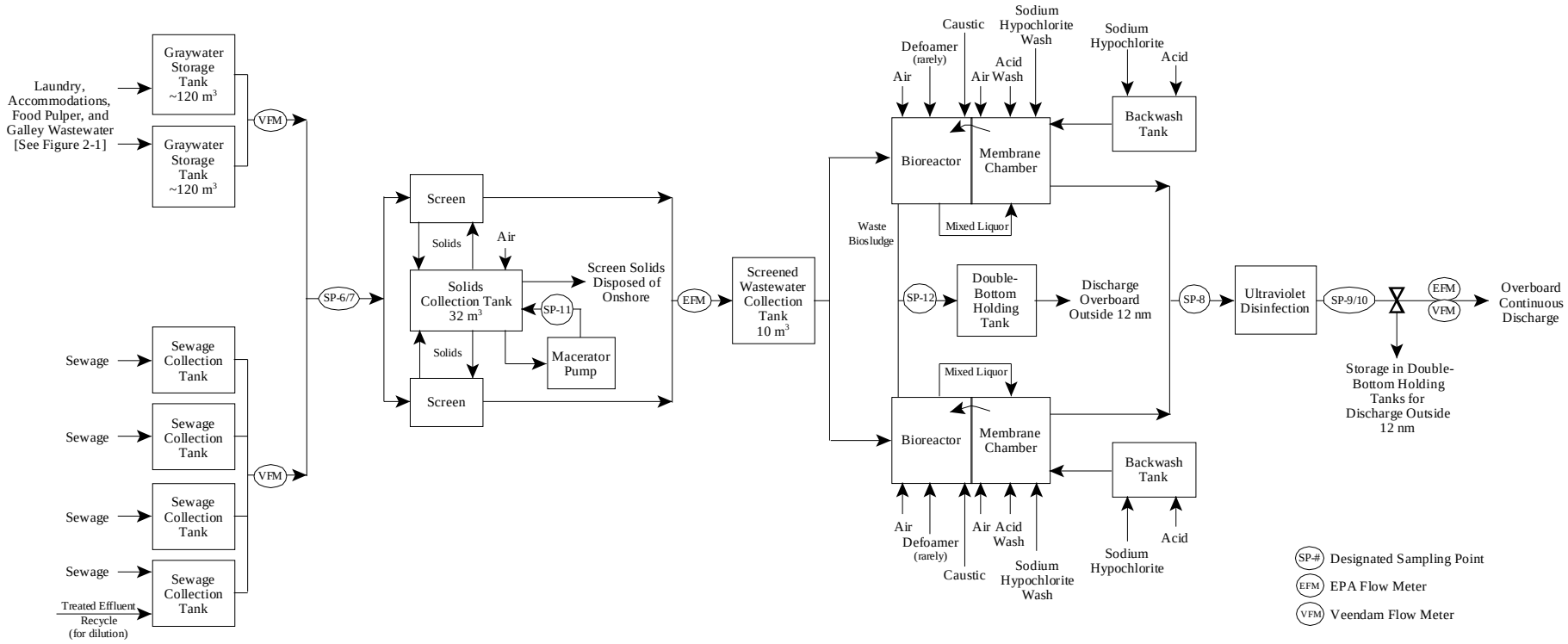

Figure 2-2. Zenon Treatment System, Holland America Veendam

Simplified diagram of the Holland America Veendam Zenon membrane bioreactor treatment system. See Table 2-1 for a list of wastewater streams in each wastewater source, and Figure 2-1 for their collection and conveyance to the treatment system.